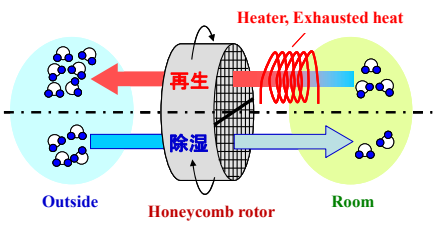
Water Desorption Behavior of Silica Gel Packed Bed with Microwave Heating

Introduction

Desiccant air conditioning system

- **Humidity** can be controlled efficiently by using **thermal energy below 373 K**.
- Sensible and latent cooling loads can be controlled **independently**.

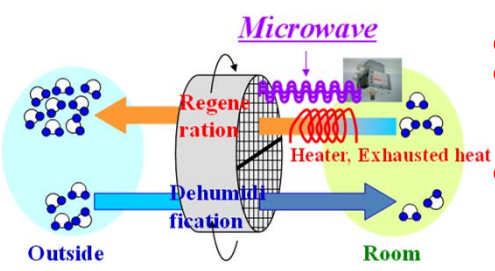


Conventional system

◎ **Simple system configuration**
One rotor performs dehumidification/regeneration continuously.

△ **Indirect heating**
Consumption of a large amount of energy

△ **Excess temperature rise during regeneration**
Low water adsorptivity of an adsorbent in dehumidification



Proposed system

◎ **Direct & rapid heating**
◎ **High heating efficiency**
Material generates heat directly by itself by absorbing microwave energy.
◎ **Selective heating**
Liquid water has a high MW absorptivity. (ε"=12.3 for water, ε"=0.123 for silica gel)

In this study

To make clear the effect of microwave energy for regeneration, dielectric loss of silica gel was measured in the presence of adsorbed water.

Water desorption behavior of silica gel packed bed was investigated experimentally.

Experimental

～ Adsorbent ～

RD type silica gel（Fuji Silysia Chemical Ltd.）

- Particle size: 1 - 2 mm
- BET surface area, S_{BET}: 632 m^2/g
- Total pore volume, V_{Total}: 0.372 cc/g
- Silanol group: 2.8×10^{21} number/ml-bed

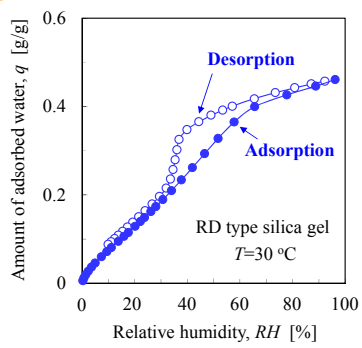


Fig. 1 Water adsorption isotherm on RD type silica gel

～ Apparatus ～

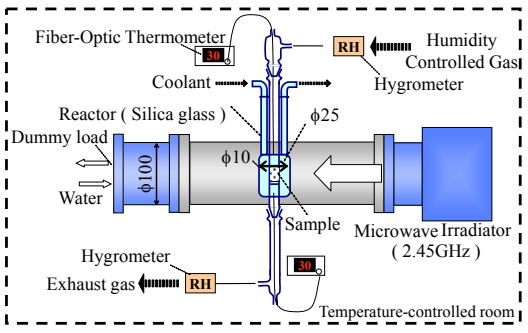


Fig. 2 Schematic drawing of experimental apparatus

～ Procedure ～

Humid nitrogen was introduced into the reactor.

Silica gel attained water adsorption equilibrium.

Microwave at 2.45 GHz was irradiated under the same humid N_2 as adsorption period.

Desorption was started.

Table Experimental conditions

Microwave power, P [W]	110 – 400
Relative humidity of N_2, RH [%]	16 – 88
Flow velocity of N_2, u [m/s]	0.21 – 1.09

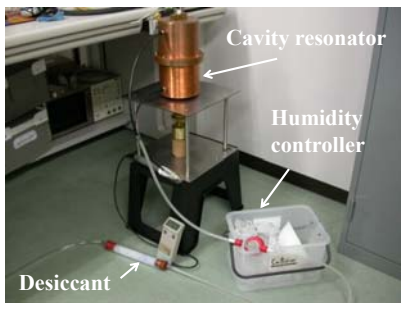
Results & Discussion

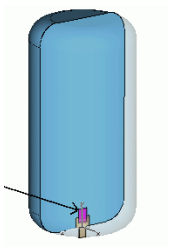
Relationship between dielectric loss and an amount of adsorbed water

Measurement of dielectric loss of silica gel at 2.45 GHz

- Resonant cavity type microwave dielectrometry
- Time Domain Reflectometry (TDR)

➢ **Resonant cavity type MW dielectrometry**





Dielectric loss, $\varepsilon'' = A\left(\frac{1}{Q_s}-\frac{1}{Q_c}\right)+B\left(\frac{1}{Q_s}-\frac{1}{Q_c}\right)^2+\bullet\bullet\bullet$

Q_s: Quality factor of cavity resonator **with** sample
Q_c: Quality factor of cavity resonator **without** sample

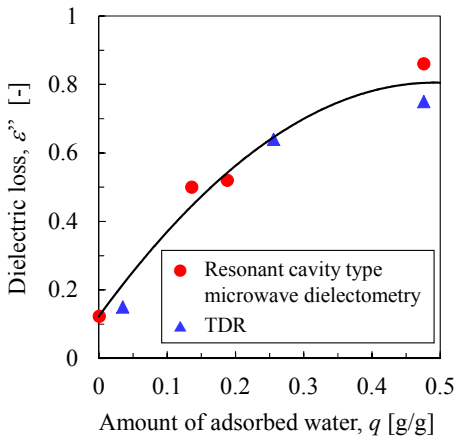


Fig. 3 Dependency of dielectric loss of silica gel on an amount of adsorbed water

✓ Amount of adsorbed water ↑
⇒ Dielectric loss ↑
✓ An increase in ε" became slow when q was over 0.3 g/g

Liquid water : ε"=12.3 ×100
Dry silica gel : ε"=0.123
⇒ **ε"=6** at q=0.5 g/g **??** (Estimated value)

ε"=0.8 at q=0.5 g/g (Exp. value)

Adsorbed water in the pore might be a different state from liquid water ??

Water desorption behavior of silica gel packed bed with microwave heating

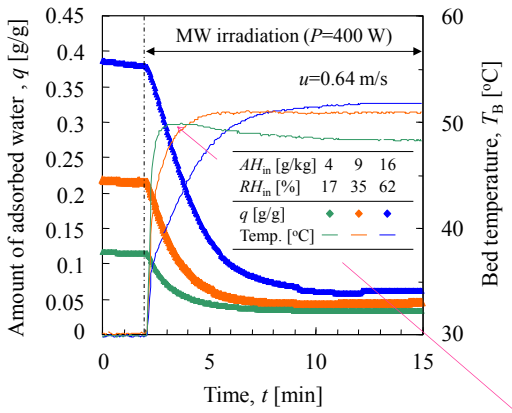


Fig. 4 Change in amount of adsorbed water and bed temperature by MW irradiation

◆ ***Amount of desorbed water***
✓ Silica gel gradually attained desorption equilibrium.
✓ **Higher initial amount of adsorbed water ⇒ Larger amount of desorbed water**

◆ ***Bed temperature***
✓ Bed temperature rose rapidly with time.
✓ **Lower initial amount of adsorbed water ⇒ Higher temperature rising rate**

Silica gel generates heat by absorbing MW by itself.
Balance between heat generation and absorption by adsorbed water at any time partially control bed temp.

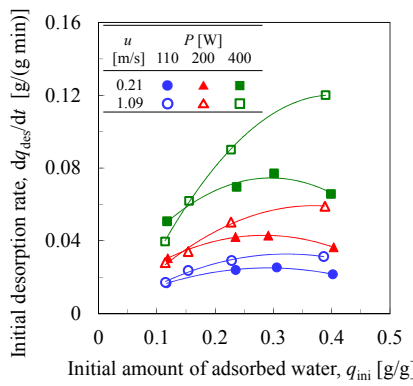


Fig. 5 Relationship between initial desorption rate and initial amount of adsorbed water

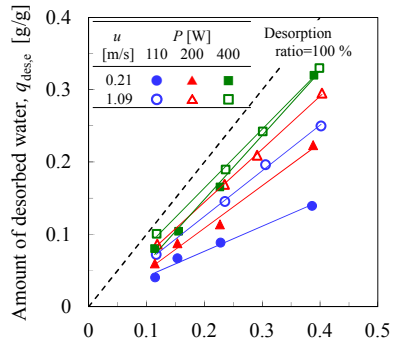


Fig. 6 Relationship between amount of desorbed water and initial amount of adsorbed water

✓ u=0.21 m/s
dq_{des}/dt had the maximum value around q_{ini}=0.3 g/g.
✓ u=1.09 m/s
dq_{des}/dt monotonically ↑ as increasing q_{ini}.
✓ These are more pronounced at higher microwave power.
✓ At $P \leqq 200$ W
dq_{des}/dt at u=0.21 m/s ≒ dq_{des}/dt at u=1.09 m/s

✓ **$q_{des,e}$ had a linear relationship with both u and P.**
✓ **Complete desorption couldn't achieved.**
Some amounts of adsorbate is required to maintain bed temperature for MW heating **??**

Conclusion

- Dielectric loss of silica gel increased monotonically as increasing amount of adsorbed water, but an increase in ε" is getting slowly when q was over 0.3 g/g.
- Water desorption and rise in bed temperature occurred instantly when microwave was irradiated to the reactor.
- Initial desorption rate had a maximum value when air was supplied at a velocity of 0.21 m/s, but it increased monotonically at u=1.09 m/s.
- An amount of desorbed water in an equilibrium state increased linearly as increasing both microwave powers and nitrogen velocities.

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